(12) UK Patent Application (19) GB (11) 2 296 459 (13) A

(43) Date of A Publication 03.07.1996

(21) Application No 9525191.4

(22) Date of Filing 07.12.1995

(30) Priority Data
(31) 4443513 (32) 07.12.1994 (33) DE

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(51) INT CL[6]
B23F 9/02 9/14

(52) UK CL (Edition O)
B3D DFEC

(56) Documents Cited
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WO 89/01838 A1 US 5257882 A US 5116173 A

(58) Field of Search
UK CL (Edition N) B3D DFEC DFEE DFEX, B3K
INT CL[6] B23F 9/00 9/02 9/08 9/10 9/14
ONLINE DATABASES: WPI

(54) Process for producing continuous corrections to a bevel gear by cutting

(57) A bevel gear eg. a gear ring having teeth curved along the length thereof is cut by cutting in one operation eg. using plunge-cut grinding or milling the concave and convex flanks of one tooth space, the cutter 1 having an axis of rotation, and the angle δ between the axis of the bevel gear 2 and a plane normal to the axis of rotation of the cutter 1 is subsequently changed to alter the shape of at least one tooth flank at a longitudinal end thereof, the relative positions of the cutter and the bevel gear along the axis of rotation being adjusted with the change of angle. By inputting numerous corrections into the CNC control a CNC-controlled machine and interpolating between them, it is possible to achieve crowned configurations and even to produce distortions or prevent distortions on the tooth flank by suitably superimposing corrections at the inner and outer ends of the tooth with corrections to the plunge position.

Fig.2

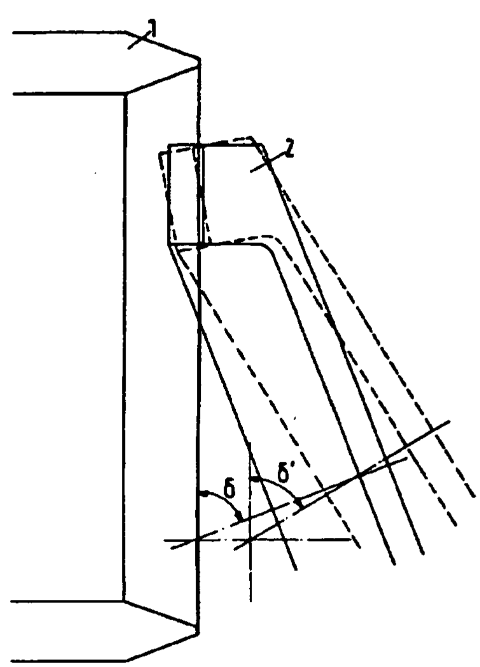

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Fig.1

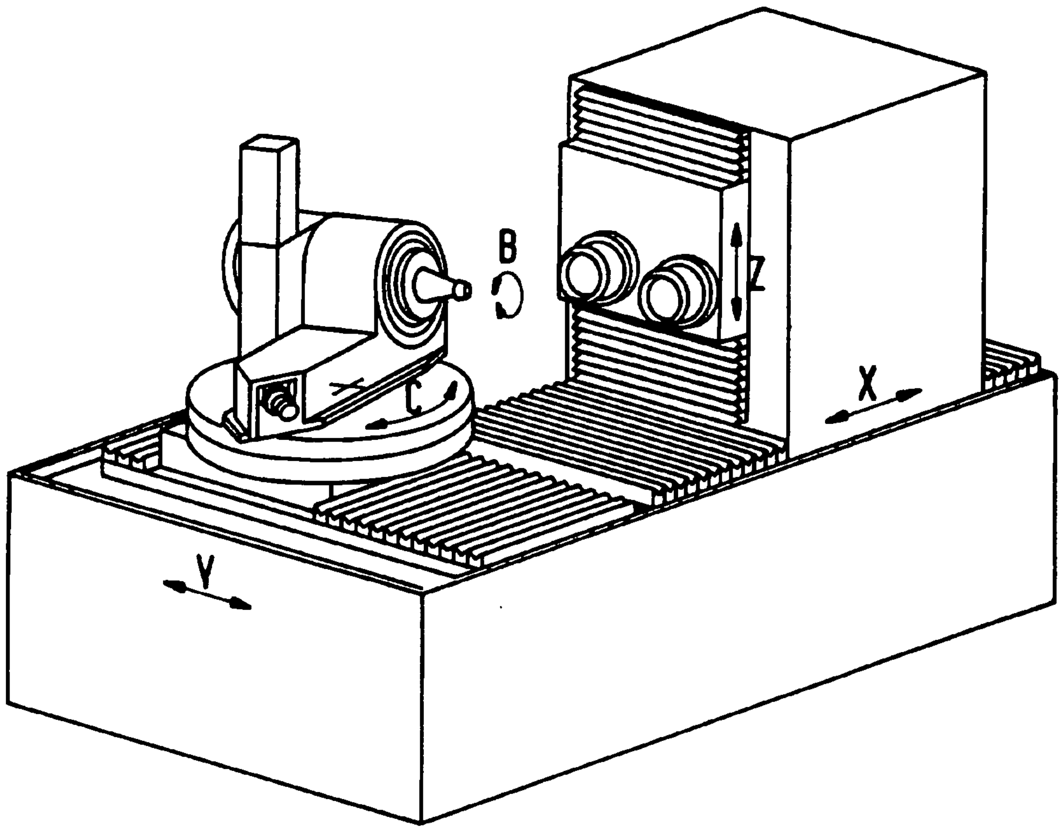


Fig.2

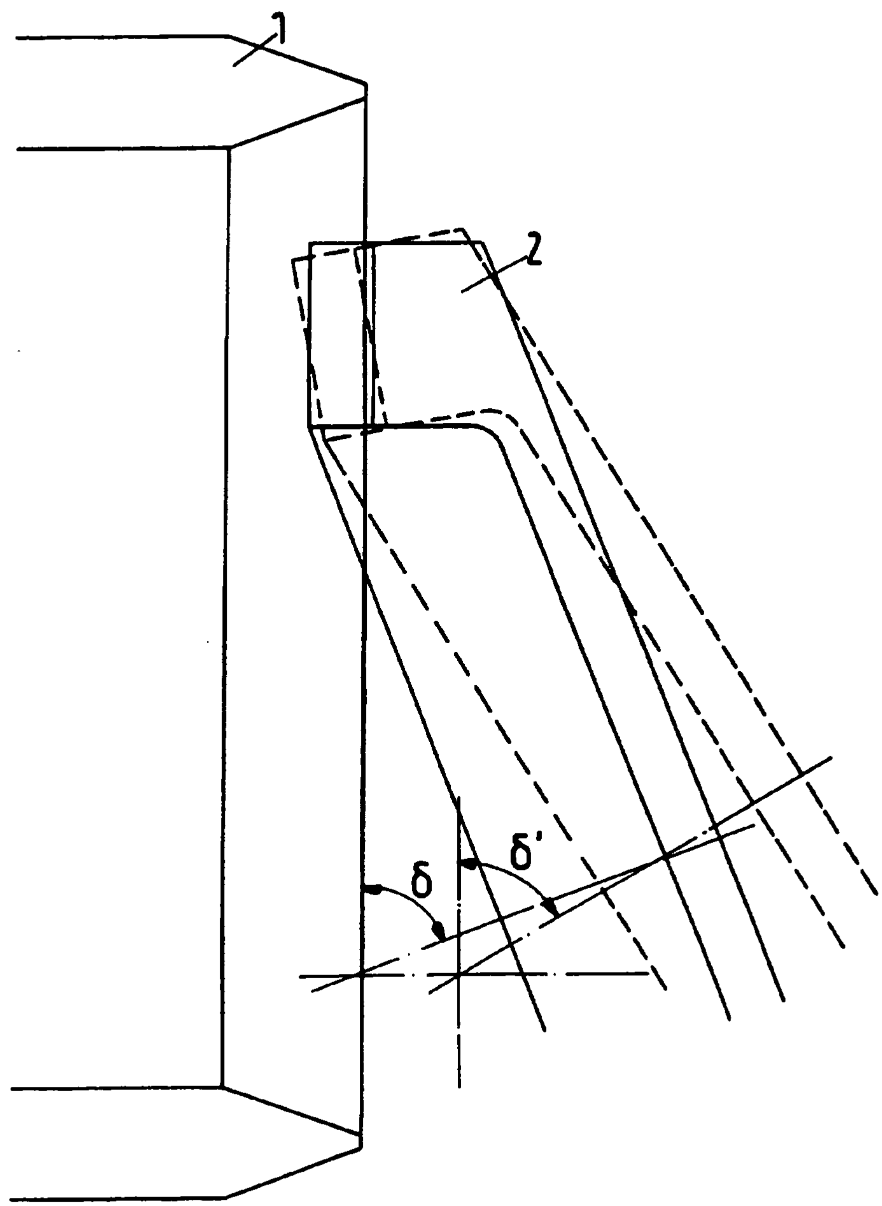


Fig.3

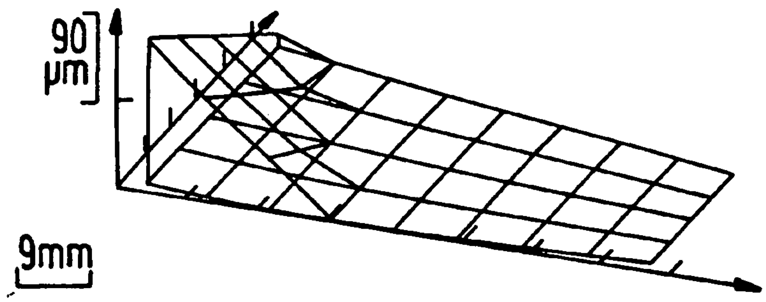


Fig.4

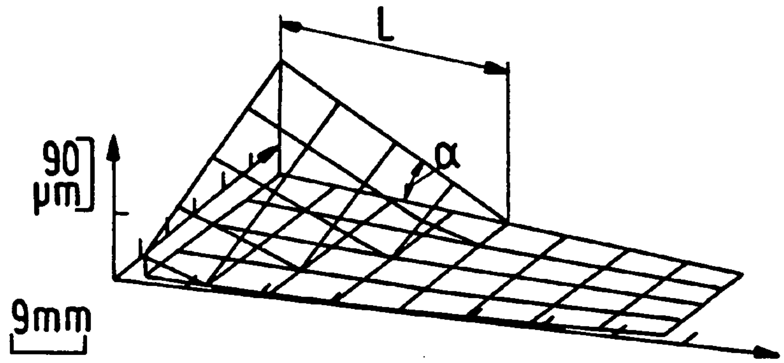


Fig.5

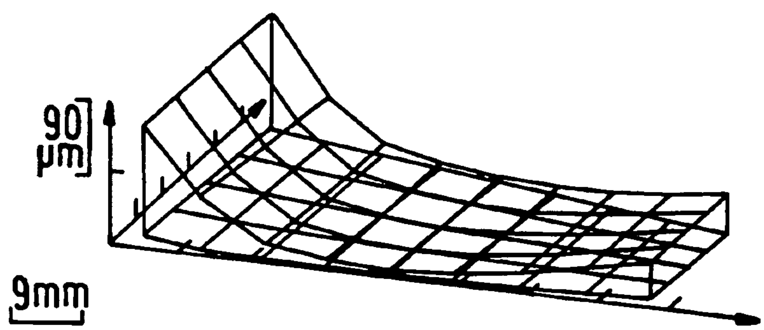
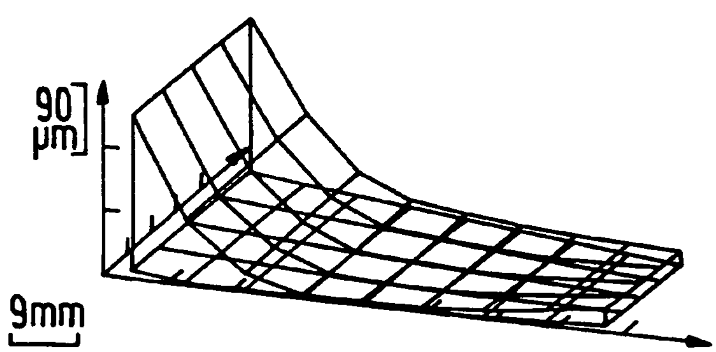


Fig.6



Process for producing continuous tooth flank corrections on curve-toothed bevel gears

The present invention relates to a process for producing continuous tooth flank corrections to curve-toothed bevel gears, for example on ring or crown gears, and particularly but not exclusively to a process in which the teeth of the bevel gear are machined in one operation on the concave and on the convex flank, for example by plunge-cut grinding or plunge-cut milling using eg. a CNC-controlled bevel gear cutting machine.

Advantageously, the process described in the invention is carried out on a universal, fully CNC-controlled bevel gear cutting machine WNC 30 made by the firm Klingelnberg. This machine has 5 controlled axes: the workpiece rotation axis, which is needed during milling to generate the correct tooth shape and during Formate® (registered trade mark of Gleason Works, Rochester, NY, USA) ring gear cutting for separating; the C-axis for the machine base angle; and 3 co-ordinate axes X, Y and Z. The second grinding disk is not necessary for the present process unless a separate roughing and finishing disk is used. The two tooth flanks of the tooth space are machined in one cut by plunging in the axial direction of the grinding disk. For this, the machine is set to the machine base angle δ. In this way an uncorrected toothing of the ring gear is obtained. It is possible, for example, to produce a ring gear with a constant tooth height, or else a ring gear with a tapering tooth-height.

In the manufacture of so-called Formate® ring gears, both flanks of the ring gear are machined in one operation on the concave and convex side by plunge-cut grinding and plunge-cut milling. Modifications to the toothing - ie. changes to the contact pattern - have hitherto been carried out only on the pinion, apart from

corrections to the longitudinal convexity and the angle of engagement, which it has also been possible to carry out on the ring gear.

For some time it has been possible to make corrections to the ring gear using the so-called "flared cup method" of Messrs Gleason. Herein the grinding disk does not plunge in one process and machine the flanks by surface contact, but rather, by inclination of the grinding wheel axis relative to the tooth space, linear contact is produced in the direction of the tooth height, and the longitudinal tooth shape is obtained by additional movements of the grinding disk relative to the wheel. It is possible to produce corrections to the tooth flank by means of the linear contact between the grinding disk and the workpiece in the "flared cup method", as compared with the area contact in plain Formate® grinding. However, the process has the disadvantage that complicated calculations are required to adjust the machine and time is wasted in the machining of ring gears as a result of the linear contact.

Reference is also made to those prior art systems known from US 5088243 and US 4780990.

Viewed from a first aspect, the present invention provides a process for cutting a bevel gear having teeth curved along the length thereof, comprising cutting in one operation the concave and convex flanks of one tooth space, said cutting being effected by a cutter having an axis of rotation, wherein the angle between the axis of the bevel gear and a plane normal to said axis of rotation is changed to alter the shape of at least one tooth flank at a longitudinal end thereof, the relative positions of the cutter and the bevel gear along said axis of rotation being adjusted with said change of angle.

Preferably the angle between the plane normal to the axis of rotation of the cutter and the axis of the bevel gear is controlled by a computer controller as is,

preferably, the relative position of the cutter and the bevel gear along the axis of rotation. In a preferred embodiment a plurality of points corresponding to a required shape of at least one tooth flank is input into the controller which interpolates between the points to control the angle between, and the relative positions of the cutter and bevel gear so as to achieve the desired flank shape.

Viewed from a second aspect the present invention provides a process for producing continuous tooth flank corrections on curve-toothed bevel gears, for example on bevel gears, in which the teeth of the bevel gear are machined in one operation on the concave and on the convex flank by plunge-cut grinding or plunge-milling using a CNC-controlled bevel gear cutting machine, wherein subsequently, by changing the machine base angle the inner and outer ends of the teeth - at the toe and/or heel - are cut back and the depth along the X-axis is adjusted accordingly, so that when the machine base angle is reduced the additional crowning or correction is generated at the outer end of the tooth, ie., at the heel, whilst in the event of an increase in the machine base angle the crowning or correction is generated at the inner end of the tooth, ie., at the toe, whilst by inputting a correspondingly large number of corrected positions into the CNC control and interpolating between them, continuous adjustment of the machine is carried out in order to produce corrections, crowned configurations or twisted configurations on the tooth flanks by correspondingly superimposing corrections at the inner and outer end of the tooth - toe and heel - with corrections to the plunge position.

Thus according to the invention crown configurations and twisted configurations can be produced on the tooth flanks continuously and with high precision.

The process makes possible corrections, crowned configurations and even twisted configurations on the

tooth flanks by suitable superimposition of corrections at the inner and outer end of the tooth with corrections to the plunge position in order to prevent or generate distortions.

The process is suitable not only for producing curvatures of this kind in plunge-cut ground gears but anywhere where Formate® bevel gears are produced, not in a Single-Cycle® surface broaching process, but by plunge-cutting. The process may be used, for example, in the Spirac process or in the production of Gleason Formate® bevel gears with bar cutters, for producing an end return (so-called Endrems®) on the inside or outside. With a suitable arrangement it is even possible to produce a breach in the edge of the outer end of the tooth.

Preferably the deviation in the angle of engagement is compensated by varying the plunge position over the Y- and Z-axis and the B-axis is adjusted accordingly.

Preferred embodiments of the invention will now be described by way of example and with reference to the accompanying, partly diagrammtic, drawings, wherein:

Fig. 1 is a perspective view of a Klingelnberg WNC 30 bevel gear cutting machine with 5 CNC-controlled axes, in principle according to the prior art;

Fig. 2 shows a grinding disk engaging with a ring gear, shown partly cut away;

Fig. 3 is a flank comparison, shown graphically in a system of co-ordinates, where only the machine base angle has been corrected (convex flank);

Fig. 4 shows a flank comparison, shown graphically, in a system of co-ordinates, where again only the machine base angle has been corrected (concave flank);

Fig. 5 shows a flank comparison after inputting a plurality of positional corrections, again shown graphically in a system of co-ordinates (concave flank);

Fig. 6 shows a similar flank comparison (convex flank).

The fully CNC-controlled bevel gear cutting machine

shown in Fig. 1 has 5 controlled axes: the workpiece rotation axis B which is needed during milling in order to produce the correct tooth shape and during Formate® ring gear grinding for separation; the C-axis for the machine base angle; and the 3 co-ordinate axes X, Y and Z.

Fig. 2 shows a grinding disk bearing the reference numeral 1 which is shown in engagement with a ring gear 2, illustrated by continuous lines in a first position. As is conventional, the 2 tooth flanks of the tooth space are machined in one cut by plunging in the axial direction of the grinding disk 1. For this, the machine is set to the machine base angle δ. This produces an uncorrected toothing on the ring gear. Fig. 2 shows a ring gear with a constant tooth height, but it is also possible to produce a ring gear 2 with a tapering tooth height.

After the tooth space has been produced by the plain Formate® process, the inner or outer end of the tooth in the toothing is cut back at the toe or heel by changing the machine base angle from δ to δ'. When the angle δ is reduced to δ' (Fig. 2), the toothing is cut back on both flanks at the outer end of the tooth. If, however, the angle δ is increased (not shown) the toothing is corrected at the inner end of the tooth. The depth must be adjusted accordingly. The size of the change of angle from δ to δ' determines the angle of pitch of the correction. This is shown in Fig. 3 for a ring gear 2 in which V is 90.00 μ and H = 9.000 mm. By adjusting the depth via the X-axis of the machine the length L of the correction can be determined (Fig. 4).

As can also be seen from Fig. 4, a deviation α in the angle of engagement is produced in the correcting range, which is dependent on the spiral angle of the gear wheel which is to be cut and the machine setting data. This deviation in the angle of engagement can be compensated by varying the plunge position of the grinding disk 2, ie. the position of the axes Y and Z.

The B-axis must be adjusted accordingly. However, at the same time, the degree of correction may also be divided between the two flanks - concave and convex - by means of the B-axis. It is possible either to divide the corrections up evenly or to correct only one flank. Infinitely variable correction is possible, so that any values can be adjusted.

The discontinuities between the correction and the uncorrected flank, shown in Fig. 3 and 4, can be avoided by inputting a number of corrected positions into the CNC-control and interpolating between them by means of the control. The results of such correction can be seen in Figs. 5 and 6, wherein only a slight cutting back is carried out at the inner end of the tooth, ie. at the toe, whereas there is a major cutting back at the outer end of the tooth, ie. at the heel, which is produced continuously and is no longer accompanied by the error in the angle of engagement, since the corresponding correction has been followed up. Such corrections may be made either on the toe and heel or separately on the toe or heel, whilst any kind of changes to the crowning can be achieved on the flank.

Claims

1. A process for producing continuous tooth flank corrections on curve-toothed bevel gears, for example on ring gears, in which the teeth of the bevel gear are machined in one operation on the concave and on the convex flank by plunge-cut grinding or plunge-milling using a CNC-controlled bevel gear cutting machine, wherein subsequently, by changing the machine base angle (δ) the inner and outer ends of the teeth - at the toe and/or heel - are cut back and the depth along the X-axis is adjusted accordingly, so that when the machine base angle (δ) is reduced the additional crowning or correction is generated at the outer end of the tooth, ie., at the heel, whilst in the event of an increase in the machine base angle (δ) the crowning or correction is generated at the inner end of the tooth, ie., at the toe, whilst by inputting a correspondingly large number of corrected positions into the CNC control and interpolating between them, continuous adjustment of the machine is carried out in order to produce corrections, crowned configurations or twisted configurations on the tooth flanks by correspondingly superimposing corrections at the inner and outer end of the tooth - toe and heel - with corrections to the plunge position.

2. A process as claimed in claim 1, wherein the deviation in the angle of engagement is compensated by varying the plunge position over the Y- and Z-axis and the B-axis is adjusted accordingly.

3. A process for cutting a bevel gear having teeth curved along the length thereof, comprising cutting in one operation the concave and convex flanks of one tooth space, said cutting being effected by a cutter having an axis of rotation, wherein the angle between the axis of the bevel gear and a plane normal to said axis of rotation is changed to alter the shape of at least one

tooth flank at a longitudinal end thereof, the relative positions of the cutter and the bevel gear along said axis of rotation being adjusted with said change of angle.

4. A process as claimed in claim 3, wherein said angle and said relative positions of the cutter and the bevel wheel are controlled by a computer controller, and wherein a plurality of points corresponding to a required shape of said at least one tooth flank is input into said controller and said controller interpolates between said points.

5. A process substantially as hereinbefore described with reference to the drawings.

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Patents Act 1977 **Examiner's report to the Comptroller under Section 17 (The Search report)**	Application number GB 9525191.4
Relevant Technical Fields (i) UK Cl (Ed.N) B3D (FEE, FEC, FEX); B3K (ii) Int Cl (Ed.6) B23F 9/00, 02, 08, 10, 14	Search Examiner M INSLEY Date of completion of Search 18 JANUARY 1996
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI	Documents considered relevant following a search in respect of Claims :- 1-5

Categories of documents

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Category	Identity of document and relevant passages		Relevant to claim(s)
A	EP 0501196 A1	(OERLIKON GEARTAC) see Figures 1, 2	
A	EP 0024301 A1	(WERKZEUGMASCHINENFABRIK) see Figures 1-3	
X	WO 92/02328 A1	(THE GLEASON WORKS) see whole document, in particular page 15, lines 16-29 and Figures 1, 4	1, 3 at least
A	WO 89/01838 A1	(THE GLEASON WORKS) see Figure 3	
X	US 5257882 A	(OERLIKON GEARTEC) see whole document, in particular column 5, line 41 - column 6, line 39	1, 3 at least
X	US 5116173 A	(THE GLEASON WORKS) see whole document	1, 3 at least

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